Technical Problems of Deploying Standard Initiative of National City True Orthophoto Mapping

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Abstract

This paper presents our preliminary experimental results on the encountered many problems when producing urban true orthoimages of downtown, where a number of high buildings present. These problems, mainly including building occlusions, street visibility, shadows, incomplete refilling, digital surface model, quality of source images, and the existing orthorectification models, may be common to true orthoimage generation in other areas with similar conditions. These problems along with our analysis to them are presented with details in the paper. Based on the analysis, this paper also proposes some possible solutions to minimize the effects of these problems on the final true orthoimage outputs.

1. Introduction

Digital orthophotos are a critical component of the National Spatial Data Infrastructure (NSDI) (Federal Geographic Data Committee, 1997; Maitra, 1998). Conventional orthorectification of large-scale aerial images only considers the geometric distortion caused by imaging process and terrains (Chen *et al.*, 1993; O'Neil, 1998; Baltsavia, 1996), because it is based on digital terrain model (DTM), which does not consider man-made buildings (Baltsavias and Kaser 2002). In many cases especially in urban area, the conventional orthorectification has encountered many difficulties (Rau *et al*., 2002). One of difficulties is that it cannot solve the problem of occlusions as a result of man-made buildings. The other is the shadow problem caused by buildings due to different solar angles when the images were taken. With urban and regional development, GIS modeling become more and more powerful tool for urban applications. Large-scale urban aerial images are an important source for such GIS modeling in urban region. The large-scale true orthoimages provide valuable information for urban GIS modeling due to their characteristics of not only representing the actual coordinate of the region but also providing useful information of the region. In this paper we intend to present the result of our experiments on generation of orthoimage from large-scale urban aerial images, for orthorectification of photographs. We focus our presentation on analysis of the problems that we encounter and the possible solutions to them. These problems may be common in generating orthoimages of urban regions and our experiences may be useful for similar work of others in this academic area.

2. Source Images and Digital Surface Model

The source images were acquired on April 17, 2000 over downtown of Denver, Colorado. The camera has a focal length of 153.022mm and was mounted on a platform of airplane with flying height of about 1650m. There were total 6 images from two flight lines. The endlap of the images is about 60% in the same flight line and only about 30% between the two neighboring flight lines (Figure 1a). The external orientation parameters of these aerial photographs are provided by Analytical Photogrammetric Inc. The digital surface model (DSM) available to this study only covers a part of the imaging area, which is the central part of the downtown area where a number of high buildings exist (Fig. 1b and 1c).

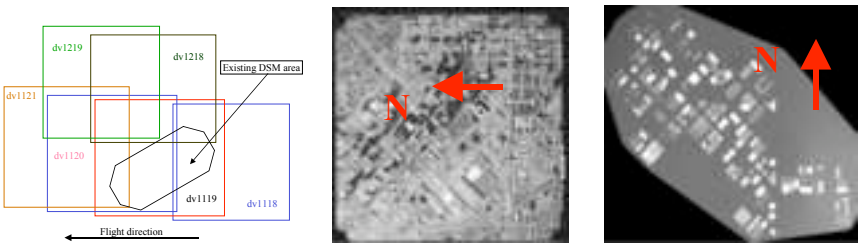

Fig. 1. (a) Relative position of available images, (b) the source image (dv119), and (c) the DSM

3. PROBLEMS AND ANALYSIS

Occlusion and ghost image: As seen in Fig. 2b, orthorectification using the traditionally differential model cannot produce a true orthoimage. Though the roofs of high buildings have been corrected to their right places, the occlusions caused by these buildings still remains in the output image. Fig 2b highlights such a building having obvious occlusion. As seen in Figure 2c, the building still leans into the street to occlude the objectives behind it. This unavoidably causes double roofs of the same building as seen in Fig. 2a and 2b: one of them represents the true ortho-viewing roof of the building, and the other is the original image of the building. This phenomenon has been dabbed as ghost image of the building (Rau *et al.,* 2002).

Shadow of the buildings: Building shadow due to angular solar illumination is also a problem in orthorectification of images. As seen in Fig. 3d, the shadow cannot be removed using the differential rectification, because this conventional method does not consider the effect of shadows.

Street visibility: In order to generate a true orthoimage with occlusions to be completely refilled, streets occluded by buildings have to be 100% visible. Here we provide a conceptual model (Fig 6) of geometric analysis for street visibility analysis. As shown in Fig. 3, the two neighboring images must overlap greatly enough to ensure the visible parts of the street on their images to reach a certain level, that is, sum of the visible parts of the street is at least equal or greater than the width of the street, i.e., $w_1+w_2 \geq W$, where W is the width of the street; w_1 and w_2 are respectively the visible parts of the street in image 1 and image 2 respectively. Thus, the visible parts are a function of many factors, including height of the buildings, the imaging altitude, the relative position of the street to the imaging center in the images.

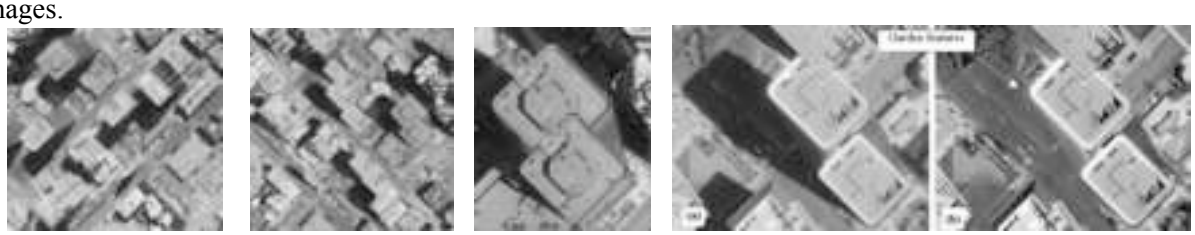

Fig. 2. (a) Source image, (b) the orthoimage generated by the differential rectification, (c) building occlusion and ghost image, (d) comparison of garden feature identification under building shadow and shadow removal by enhancement

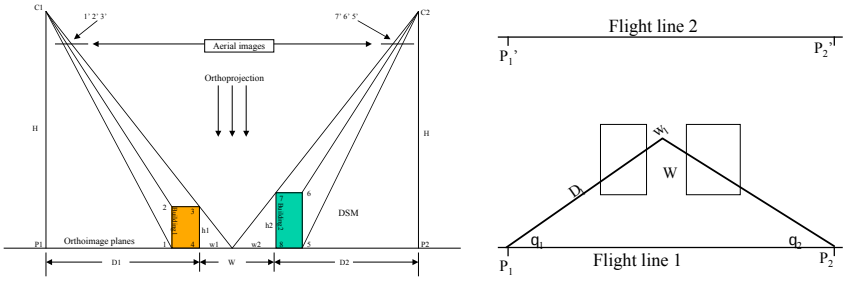

Fig. 3. A conceptual model of visibility analysis

Occlusion re-filling: Since building occlusion is unavoidable in large-scale urban images, it is natural to consider to identify the occlusion and to refill it from neighboring slave images. To this end, it is better to use the images acquired from the same flight mission for minimizing spectral difference of the refilled areas. However, refilling may not be complete due to visibility problem of the available images. Sometimes it is not possible to find enough slave images to completely refill the occlusions. This is especially true for high buildings locating at the edge part of source image, where skew viewing of imaging camera makes the occlusion too large. Fig. 4 illustrates one example of this fact

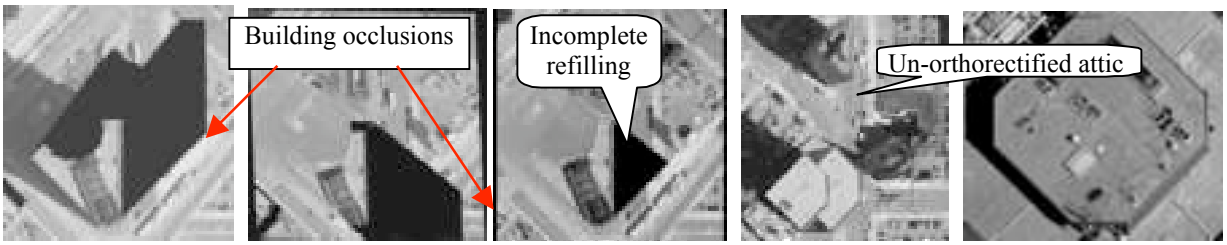

Fig. 4. Building occlusion in the master image (a) and in the slave image (b), and (c) result by refilling, (d) image position, and un-orthorectified image (d)

Representation of DSM: Orthorectification is based on the available DSM. If a DSM does not exactly represented the urban building, it will largely effect the quality of orthorectification.

Accuracy of rectification: In order to re-fill the occlusion, we conduct the orthorectification to several neighboring images acquired from the same photogrammetric mission. Fig. 5 compares the details of the orthorectified images from two neighboring images. In both case, the building roof has not been accurately orthorectified to their position, but the accuracy in Fig. 5a is higher than that in Fig. 5b. This fact demonstrated that the same DSM produces might produce different accuracy of orthorectification in different image.

Radiometric difference: Generation of true orthoimages usually requires removal of building occlusions either by refilling or mosaicking from neighboring slave images. When the tone of the slave images is different from that of the master image, this usually produces an obvious radiometric contrast on both sides of the seam line.

We also found out other problems, such as over-transfer and loss of information (see Fig 5), i.e., after orthorectification, some over-transfers of non-roof features are seen in the output image. The over-transfer parts have the same shape as the corresponding building roof. Since the building size is fixed in the DSM, the over-transfer of roof has consequently caused another problem: information loss of roof on the other side.

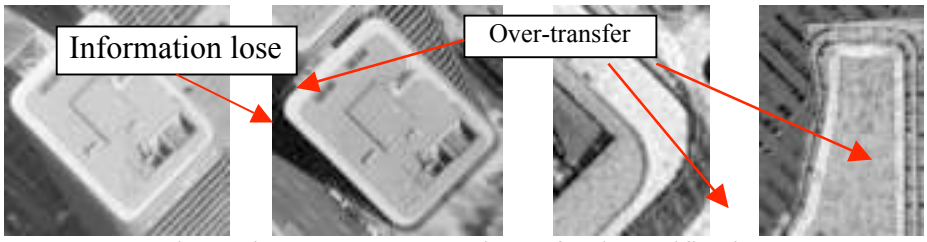

Fig. 5.The accuracy comparison of orthorectification

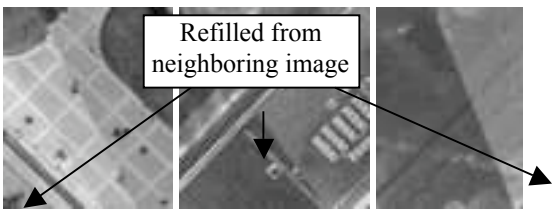

Fig. 6. Radiometric contrast on both sides of the seam line

4. Conclusion

Orthorectification of large-scale aerial images in urban area has been examined in the study. Using the differential rectification, we perform experiments on downtown Denver, CO for generation of orthoimage. Several problems encountered in the experiments have been presented with detailed analysis in the study. Our results from the experiments indicate that conventional method for orthorectification cannot provide a true orthoimage. The main problem is that it cannot automatically identify building occlusions in urban area. Thus double building roofs dubbed as ghost images are usually seen in the output image. Another problem is building shadows that reduce image quality. The only way to produce a true orthoimage without occlusions is to identify occlusions and refill them from neighboring images. Supposed that building occlusions can be successfully identified, the refilling still encounters the problem of visibility. If the occlusions were not 100% visible in the source images, the problem of incomplete refilling may exist. This is especially true for high buildings relatively afar from imaging center of the scene.

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